

Initial Injection Pressure for Dental Local Anesthesia: Effects on Pain and Anxiety

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This study quantitatively assessed injection pressure, pain, and anxiety at the start of injection of a local anesthetic into the oral mucosa, and confirmed the relationship between injection pressure and pain, as well as between injection pressure and anxiety. Twenty-eight healthy men were selected as subjects and a 0.5-inch (12 mm) 30-gauge disposable needle attached to a computer-controlled local anesthetic delivery system (the Wand) was used. A 0.5 mL volume of local anesthetic solution was injected submucosally at a speed of either 30 or 160 s/mL. Three seconds after the start of local anesthetic injection, injection pressure was measured and pain and anxiety were assessed. Injection pressure was measured continuously in real time by using an invasive sphygmomanometer and analytical software, and pain was assessed on the Visual Analogue Scale and anxiety on the Faces Anxiety Scale. A significant correlation was evident between injection pressure and pain ($r_s = .579$, $P = .00124$) and between intensity of injection pressure and state anxiety ($r_s = .479$, $P = .00979$). It is therefore recommended that local anesthetic be injected under low pressure (less than 306 mm Hg) to minimize pain and anxiety among dental patients.

Key Words: Local anesthetic initial injection pressure; Pain; Anxiety.

Patients receiving dental infiltration anesthesia generally experience anxiety related to the injection and pain resulting from puncture of the oral mucosa and tissues or injection of anesthetic solution. When promoting safety of dental care, it is therefore important to establish a method of local anesthetic injection that does not give rise to pain and anxiety. Slow, low-pressure injection is the key to painless and comfortable delivery of local anesthetic.¹ However, standards for injection speed and pressure have not been clarified.

In the present study, injection pressure, pain, and anxiety at the start of a local anesthetic injection into the oral mucosa was quantitatively assessed, and the relationships between injection pressure and pain and between injection pressure and anxiety were determined.

SUBJECTS AND METHODS

Subjects

The subjects were 28 healthy men ages 26.7 ± 3.6 years (mean \pm SD) who were clinical trainees and interns at the School of Dentistry at Health Sciences University of Hokkaido. Average scores for the trait anxiety inventory² (Japanese version of the State-Trait Anxiety Inventory form X [STAI X-II]) were 45.8 ± 9.5 (mean \pm SD) with a range of 29–70. Written consent was obtained from all subjects after explaining the primary objectives of the present study. Each subject was assigned a number. Odd-numbered subjects received a low-speed injection, whereas even-numbered subjects received a high-speed injection. The operator performing the injections was not informed of the subject numbers or the injection speed.

The Needle and the Syringe

For the injections, a computer-controlled local anesthetic delivery system called the Wand (Figure 1A) was

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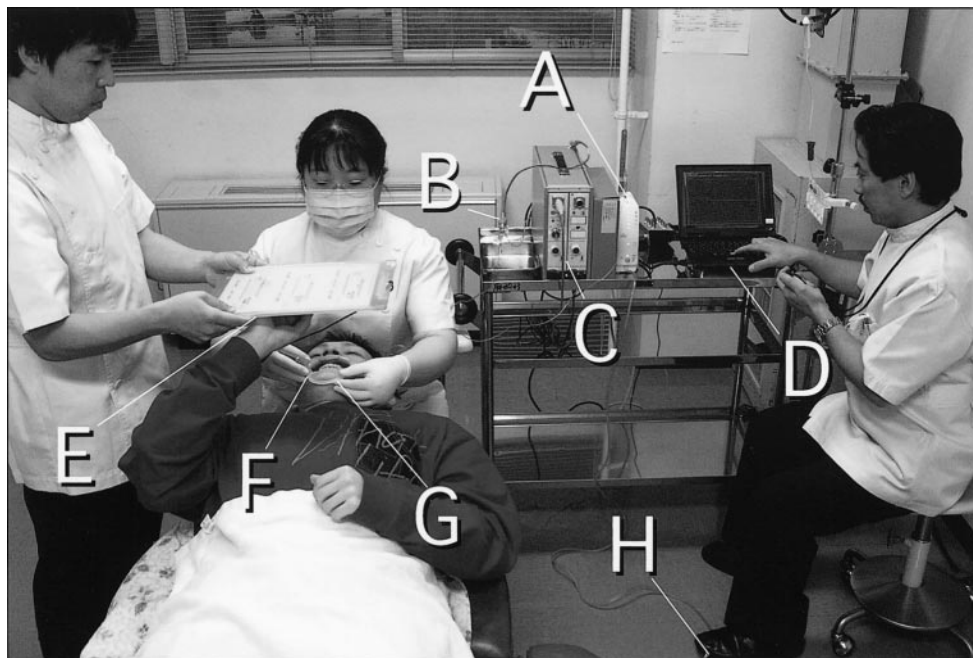


Figure 1. Measurement of injection pressure during local anesthetic. A, A computer-controlled local anesthetic delivery system syringe. B, Pressure transducer and connection to tubes. C, Invasive sphygmomanometer. D, Analytical software and personal computer. E, The patient marks the perceived level of pain and anxiety on the linear Visual Analogue Scale and Faces Anxiety Scale. F, Puncture site and injection of local anesthetic. The hand piece, shortened to half-length, is held like a pen. G, Cheek retractor pulling the lower lip. H, The syringe's foot pedal.

used, as well as a special 0.5-inch 30-gauge disposable needle (outer diameter 0.30 mm, length 12 mm) (Misawa Medical Industry Co Ltd, Tokyo, Japan). This device is composed of a syringe body (specifically designed for local anesthetic cartridges), a syringe-and-needle hand piece, ultrafine tubing connecting the syringe body to the syringe-and-needle hand piece, and a foot pedal to operate the injection. The injection speed of this device could be adjusted to 2 levels: fast (30 s/mL) or slow (160 s/mL).³ The operator using the hand piece did not use the foot pedal to inject the anesthetic. Injection speed was randomly adjusted to slow or high, and the hand-piece operator and subjects were not informed of the injection speed.

Local Anesthetic Solution

A 2% lidocaine hydrochloride with 1 : 80,000 epinephrine (supplied in a dental local anesthetic cartridge) was used as a local anesthetic.

Needle Puncture Site and Injection of Local Anesthetic Solution

The operator held the hand piece like a pen, resting it on the right ring finger and the pinkie. While stretching the movable labial gingival mucosa at the right lower

canine position, the operator pointed the needle bevel away from the labial side to perform submucosal puncture (Figure 2A). The operator used approximate injection speeds of either 30 or 160 s/mL to inject 0.5 mL of local anesthetic solution submucosally while visually checking enlargement of the bulge at the injection site (Figure 2B). The mean injection time was 16.35 seconds (14.6–17.0 seconds) for the high-speed group ($n = 14$) and 94.57 seconds (93–98 seconds) for the low-speed group ($n = 14$).

Measurement of Injection Pressure and Assessment of Pain and Anxiety

The start of local anesthetic injection was within 3 seconds, and injection pressure was measured and pain and anxiety was assessed.

Measurement of Injection Pressure. For the connections between the pressure transducer and the injection apparatus, the methods of Rood⁴ and Pashley et al⁵ were modified as follows. A Nihon Kohden pressure transducer (TP300T; Co Ltd) was connected between the hub of the needle and the syringe (Figure 1B) and measured injection pressure continuously in real time from immediately before puncture to removal of the needle by using an invasive sphygmomanometer

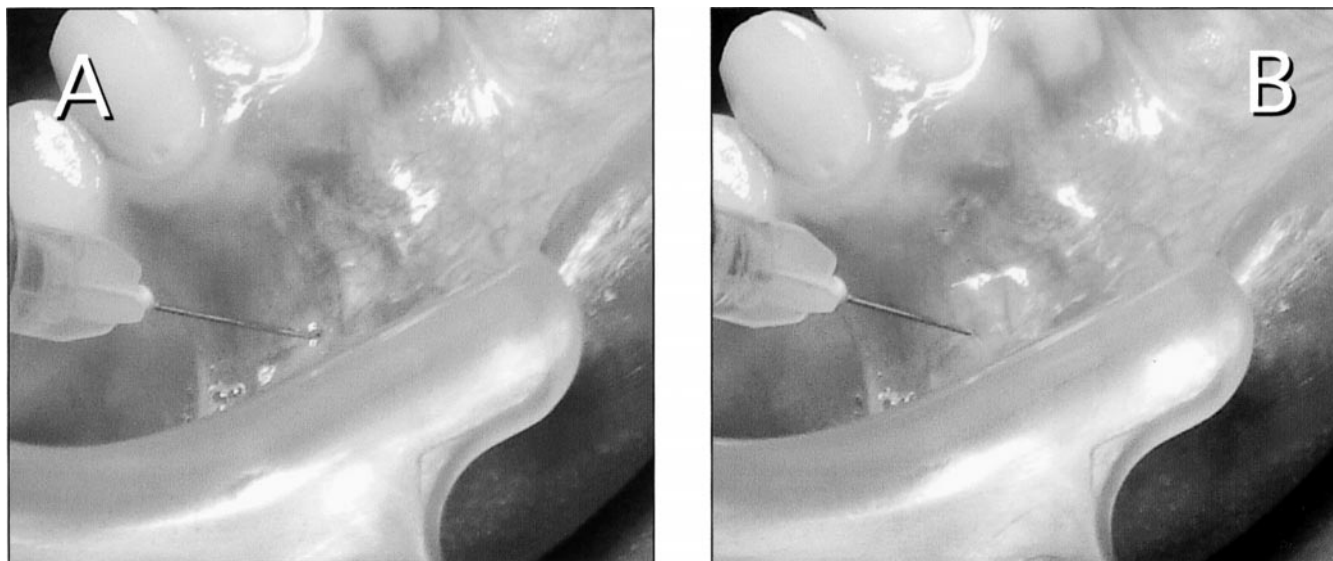


Figure 2. A buccal infiltration injection into the mandibular anterior region with a needle and computer-controlled syringe for local anesthetic (2% lidocaine with 1 : 80,000 epinephrine). A pressure transducer was connected between the hub of the needle and the hand piece. A, Needle puncture: the needle bevel was pointed away from the labial side to perform submucosal puncture while stretching the labial gingival mucosa at the right lower canine position. B, Start of injection: enlargement of the bulge at the injection site during infusion speeds of either 30 or 160 s/mL.

(AP-641G; Nihon Kohden Co Ltd, Tokyo, Japan) (Figure 1C) and analytical software (gmview 2-CORE; GMS Co Ltd, Tokyo, Japan) (Figure 1D). The sphygmomanometer could measure a maximum pressure of 2,000 mm Hg.

Quantitative Analysis of Pain Intensity. Pain was assessed using the Visual Analogue Scale (VAS). Operationally, the VAS is usually a horizontal line, 100 mm in length,⁶ and labeled with the phrase “No pain” at the left end and the phrase “Unbearable pain” at the right end. The subject marks the perceived level of pain on this linear scale (Figure 1E), indicating a numerical score between 0 and 100 (Figure 3).

Assessment of Anxiety. Anxiety was assessed using the Faces Anxiety Scale (FAS). The level of anxiety is indicated by a number between 0 and 5, represented on a horizontal 100-mm line by 6 drawings of facial expressions, ranging from a smiling face at the left end to a very anxious face at the right end (Figure 4). The subject is asked, “What is your current level of anxiety?” and responds by marking the linear scale. Anxiety levels are represented by the corresponding numerical values, rounded to 2 decimal places. FAS is known to be positively correlated to state anxiety of STAI² (Japanese version of the State-Trait Anxiety Inventory form X), with a FAS score of 3 corresponding to “high anxiety state” on the STAI and a FAS score of 4 or higher corresponding to “severely high anxiety state.”⁷

The FAS and VAS were printed on a sheet of paper and positioned next to each subject so that the scales could be marked at the time of injection. An assistant was also on hand to explain the rating system to the subjects.

Statistical Analysis

Correlations between injection pressure and pain and between injection pressure and anxiety were analyzed by using Excel (Microsoft, Redmond, Wash). Spearman rank correlation coefficients (r_s) were calculated.

RESULTS

Relationship Between Intensity of Pain and Injection Pressure

There was a significant correlation between the intensity of pain and pressure at the start of injection ($r_s = .579$, $P = .00124$, 2-sided test). Injection pressure ranged from 33 to 496 mm Hg, and VAS pain scores ranged from 0 to 86 (Figure 5).

Relationship Between State Anxiety and Injection Pressure

There was a significant correlation between state anxiety and pressure at the start of injection ($r_s = .479$,

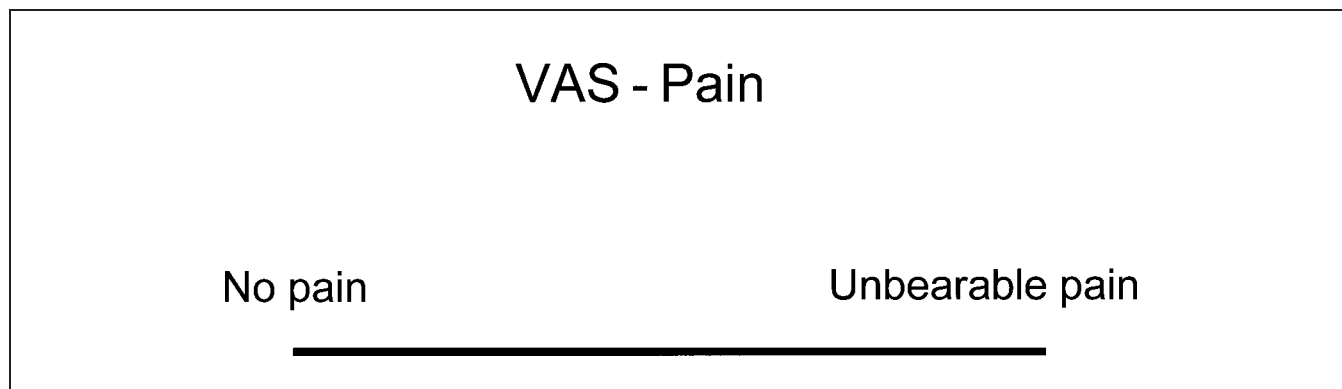


Figure 3. Pain was assessed on the standard Visual Analogue Scale. On a horizontal 100-mm line, patients indicate their level of pain by choosing a numerical score between 0 and 100.

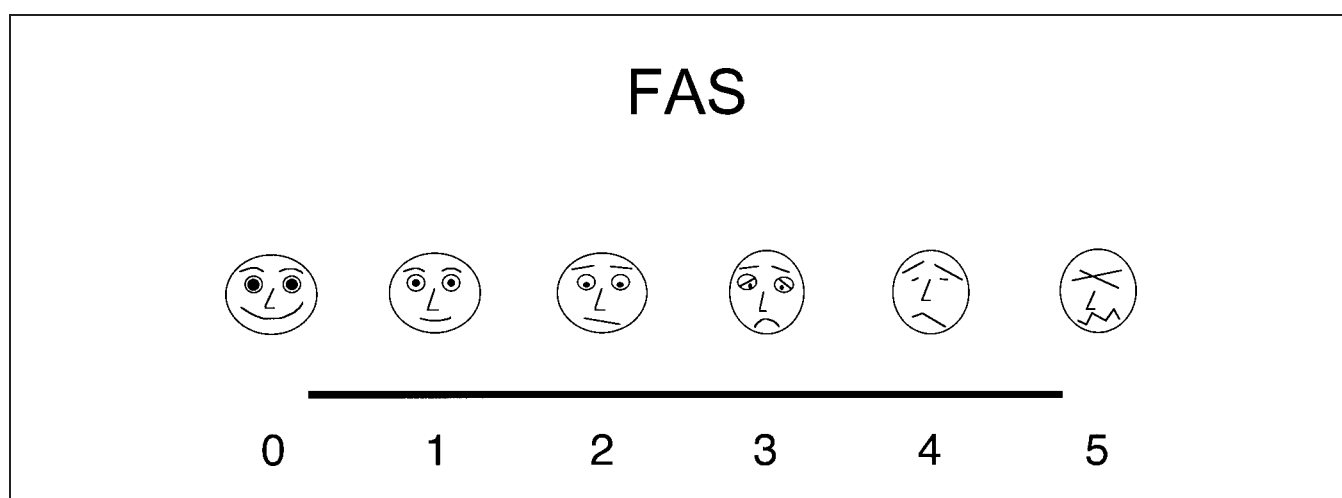


Figure 4. Anxiety was assessed on the standard Faces Anxiety Scale. On a horizontal 100-mm line, patients indicate their level of anxiety by choosing a number between 0 and 5 that also corresponds to a drawing of a facial expression ranging from smiling (far left) to extreme anxiety (far right).

$P = .00979$, 2-sided test). FAS scores at the beginning of injection ranged from 0.9 to 4.5 (Figure 6).

DISCUSSION

In the present study, 2% lidocaine hydrochloride solution with 1:80,000 epinephrine was injected submucosally. Positive correlations were discovered between pressure at the start of injection and intensity of pain and anxiety at this time. It is therefore recommended that the local anesthetic should be injected under low pressure to minimize pain and anxiety among patients.

The present results indicated a quadratic relationship between injection pressure and both pain and anxiety, with a VAS pain score of 51. The target value of the low-pressure injection for reducing pain was 51 mm on the VAS, which can be considered as moderate pain (85/170 mm) on the Heft-Parker VAS,⁸ and corre-

sponded to injection pressure of 306.39 mm Hg. A FAS score of 3 (high level of state anxiety)⁷ corresponded to 363.44 mm Hg. Therefore, to minimize pain and anxiety, it is important for dentists to inject at a pressure of less than 306 mm Hg at the start of local anesthetic injection.

Regarding factors affecting injection pressure in dental local anesthetic injection, Pashley et al⁵ performed infiltration anesthesia of the palatal mucosa in dogs. Eleven dentists were involved in their study, which measured maximum injection pressure. The average maximum injection pressure was 11,322 mm Hg. The following factors were determined to influence pressure: volume injected into the tissue per unit time; permeability of the injected solution into bone, soft tissue, and blood vessels; and effects of tissue pressure and stretching of the movable mucosa caused by the volume of the injected solution. In infiltration anesthesia, the injected solution takes a few minutes to permeate the dental

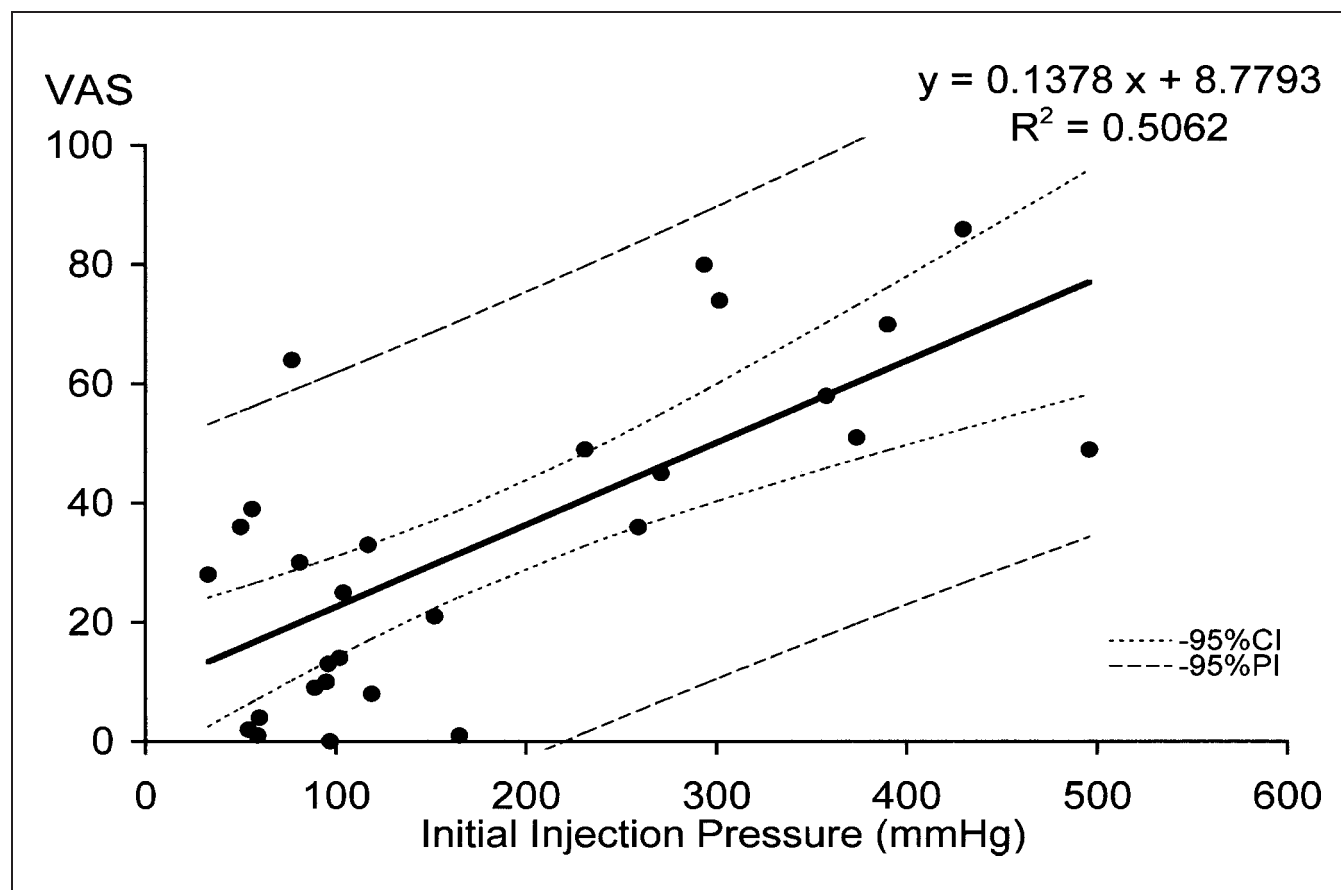


Figure 5. The relationship between Visual Analogue Scale pain score and local anesthetic injection pressure at the start of injection. The regression line is plotted in bold. Injection pressure was a significant predictor of increased pain.

pulp and induce anesthesia at this level. However, blockade of the oral mucosa nociceptive receptors is thought to occur in a few seconds, resulting in anesthesia of the oral mucosa.

Birchfield and Rosenberg⁹ reported that the intrapulpal anesthetic method for the dental pulp utilizes both the action of the local anesthetic and the effect of pressure. In this regard, fine nerve fibers exhibit higher resistance to pressure and ischemia when compared with thick nerve fibers.¹⁰ In a study of intrapulpal injection, Van Gheluwe and Walton¹¹ demonstrated no significant differences between saline solution and 2% lidocaine with 1 : 100,000 epinephrine. Thus, injection pressure can be a factor in obtaining an anesthetic effect. However, a search of the literature revealed no other reports on the real-time measurement of injection pressure at the start of injection that recorded pain and anxiety in the same experimental system with volunteers as subjects.

Regarding the relationship between injection speed of dental local anesthetic and pain, Nagasawa et al¹² reported a correlation between pain and injection speed of local anesthetic to the interdental papillary gingival

mucosa in systemically anesthetized rats. Moreover, Primosch and Brooks¹³ reported that pain was less when 0.3 mL of a local anesthetic solution was injected into the hard palate mucosal membrane at a low speed (161 s/mL) than when injected at a high speed (29 s/mL). These findings were in accordance with those of the present study, in which 0.5 mL of a local anesthetic solution was injected with a computer-controlled local anesthetic delivery system at a low speed (94.6 ± 1.6 seconds) and a high speed (16.7 ± 0.5 seconds) and pain and anxiety were measured. The present results also confirmed the findings of a previous study, which found that injection pressure at low speed is significantly lower and pain is also much less severe.¹⁴ Chemical pain stimuli are obviously affected by properties of the injection solution, such as pH and osmotic pressure ratio.¹⁵ However, in a current search of the literature, no reports besides the present study have been published on the measurement of injection pressure to support the finding that injection pressure is related to pain and anxiety.

In the current study, it was found that anxiety at the start of injection was correlated with injection pressure.

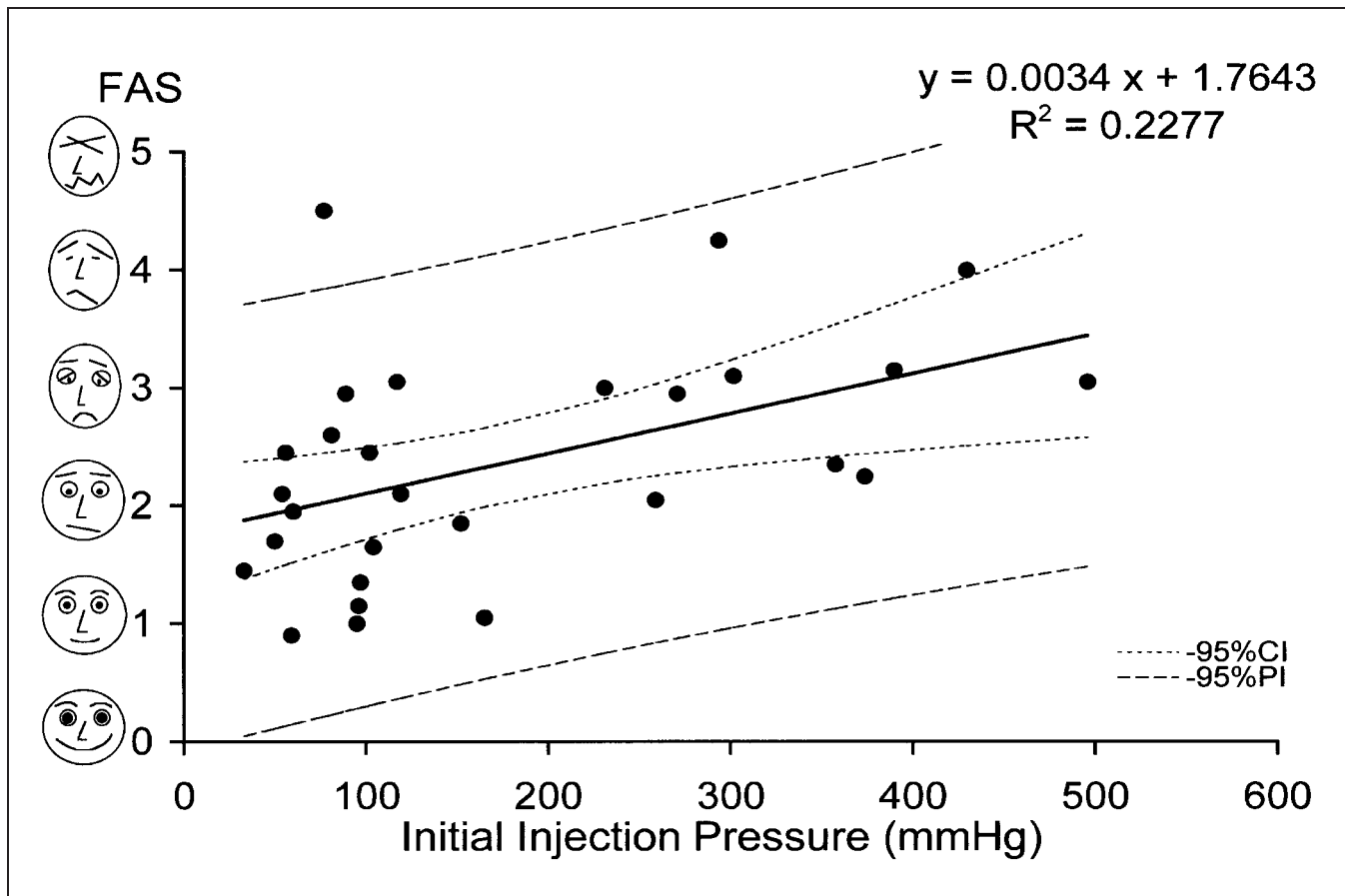


Figure 6. The relationship between Faces Anxiety Scale score and local anesthetic injection pressure at start of injection. The regression line is plotted in bold. Injection pressure was a significant predictor of increased anxiety.

In addition to the pain caused by injection pressure, other factors elevating anxiety are assumed to include visual, auditory, and olfactory stimuli. According to a previous study regarding the relationships between injection and patients' psychological characteristics in terms of anxiety, patients with high trait anxiety tend to have low pain thresholds¹⁶ and become extremely anxious upon seeing a large pistol-type metallic syringe.¹⁷ Dental injection needles generally have an external diameter of over 0.28 mm and a length of over 16 mm.¹⁸

In clinical practice, reduction of pain and anxiety must be promoted.¹⁹ In the present study, to observe the impact of injection pressure at the time of injection on pain and anxiety, neither anesthetic gel was applied topically nor was nitrous oxide inhalation sedation used before needle insertion. As a result, all subjects complained of pain on mucosal puncture and upon injection of anesthetic. To maximize the likelihood of a painless infiltration anesthetic procedure, it is necessary to use a very fine needle²⁰ and to apply topical anesthesia or inhalation sedation of 30% nitrous oxide and 70% oxygen.²¹ Moreover, many accidents occurring in the field of dentistry are induced by injection of local anesthetic. On the

basis of the present results, it is therefore important to decrease pain and anxiety of a local anesthetic injection by injecting at pressures less than 306 mm Hg under the movable mucosa.

CONCLUSION

A dental local anesthetic solution was injected under the movable mucosa in volunteers. A positive correlation was evident between injection pressure and intensity of pain at the start of injection. Anxiety level at the start of injection was also found to be directly related to injection pressure.

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